INDUSTRIAL SATURNISM WITH SPECIAL REFERENCE TO THE ACUTER FORMS OF THE CONDITION

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Saturnism, plumbism, and lead poisoning are three synonymous terms employed to denote a condition of grave chemical toxaemia, occurring in persons ex--posed to the effects of lead in one or other of its forms.

This poisoning occurs the more readily when a person comes in contact with one or more of the sol--uble salts of lead, and, as will be shewn later, there is an individual idiosyncrasy to the effects of this metal whereby certain persons, notably females, are especially prone to suffer from its baneful in--fluences.

The purpose of this thesis will be to des--cribe the acute abdominal lead poisoning so rampant in this area (Fife), and, later, to complete the study of this disease in its varied chronic forms from facts culled from literature.

In the first instance it might be of inter--est to show by which channels lead compounds may enter the human body and under what circumstances absorption may take place. There are three modes of

entrance:-

1. By absorption through the skin (inunction).
2. By ingestion through the gastric mucosa.
3. By absorption through the respiratory mucosa.

INUNCTION AND SKIN ABSORPTION.

It has been shewn, though denied by Tan--querel Des Planches, that lead salts can be absorbed through the skin, in as much as persons have been known to develop typical lead poisoning through the use of cosmetics and hair dyes,- other sources of poisoning being excluded.

INGESTION.

In his monograph on this subject, Oliver describes a series of experiments which show that lead can be ingested through the gastric mucosa after having first undergone chemical change in the stomach. The gist of these experiments shows that lead carbon--ate (lead white), which was the substance used, is acted upon by the Hydrochloric acid of the gastric juice, and, in his opinion, transformed into lead chloride, which is a highly soluble and diffusible salt. (Lead chloride is diffusible through parchment membrane, which was used on the occasion). Again, it was shown that pepsin alone has no effect on the

digestion of lead substances and even retards the sol--vent action of the Hydrochloric acid. Most lead was absorbed when Hydrochloric acid was present alone without either pepsin or albumen. During protein digestion, therefore, less lead is dissolved than when the stomach is empty.

This fact is taken advantage of in the prophylaxis of lead poisoning,- lead workers being instructed either to consume a sufficient breakfast before starting the day's work, or to take advantage of a supply of fresh milk, which is generally provid--ed at the expense of the Employer; and it depends upon the fact that during protein digestion there is much less free Hydrochloric acid present in the stom--ach, and therefore available for the transformation of insoluble into soluble lead compounds.

INHALATION.

The respiratory system, however, is the route par excellence by which lead gains access to the body, and in this connection much useful information has been obtained by the Home Office through the ac--tivities of their chemical staff. The observations were taken in a number of ship-breaking yards, such as exist in this area, where obsolete vessels (naval and mercantile) are broken up by means of the Oxy-Acetylene

flame.

It should be observed first that lead is extensively used to fill cavities between the armour plating and is often present in large quantities, so also in the paint which, by reason of frequent applica--tion, is often of considerable thickness. The oxy-acetylene flame is played on the part of Hull or Deck to be divided, and, immediately the red lead (lead oxide) is volatilised by the heat, a dense cloud of very fine particles being formed, which, unless pre--cautions are taken to the contrary, are inhaled by those working in the vicinity. Thus is lead poison--ing produced as it is found in this area.

Under high magnification (600 diameters) the fume from cutting is so fine as to be completely held back only by a layer of cotton wool 6 inches thick, and is seen to consist of an enormous number of trans--lucent colourless particles chiefly .5 of a micron and less in diameter, discrete, but so dense as to be almost touching, irregular in form and apparently more flaky than globular.

These findings show (1) that the fumes are particulate in character; (2) that they may be present and may reach considerable density though not obvious even in bright sunlight; and (3) that the density is

greatest in confined and sheltered places i.e. below decks. (Home Office Memorandum April 1925).

Poisoning, therefore, is brought about by inhalation of fine lead dust in a nebulous state, which, reaching the respiratory mucous membrane of the bronchi and bronchioles is transformed into car--bonate and later into the soluble bicarbonate, by interaction with the carbon dioxide in the expired air (Oliver).

It is also stated in this connection by Legge & Goadby that particles of lead may be ingested unaltered by phagocytosis and thus pass into the pul--monary interstitial tissues, without chemical altera--tion being demonstrable there histologically in the same way as any other solid particles as in siderosis, silicosis and anthracosis. This last method of absorption is by far the most disastrous in its effects and rapid in its production of symptoms. Ex--periments carried out in the Government laboratory prove that the amount of lead breathed daily by an oxy-acetylene burner is about twenty five times as great as the minimum dose of lead, which, if inhaled daily, will in time cause chronic lead poisoning. (Neuritis and arterio-sclerotic kidney). Observa--tions made by Alderson also show that absorption by respiration is more productive of deleterious conse-

-quences than any other method of receiving the metal. Therefore, in cutting up the hull plates of ships or any other material with painted surface, the paint should be scraped away for a considerable width along the line of cut, and thereby eliminate one source of poisoning.

Having thus gained entrance into the body, lead is conveyed to the various tissues and stored as an insoluble albuminate, or perhaps merely as a compound of albumen and lead chloride. Lead is never present in the blood or tissues to any great extent when the organs are quantitatively examined; but there is sufficient evidence in the literature (Oliver) to prove that the central nervous system certainly has the greatest proportion, especially where death has been due to lead eclampsia, but on the other hand no lead may be demonstrated in the brain even after fatal convulsions.

Cases of lead poisoning are divisible into four classes, two of which are acute and two subacute or chronic, viz:-

1. Acute abdominal plumbism.
2. Lead encephalopathy or eclampsia.
3. Lead Palsy.
4. Chronic (arteriosclerotic) kidney.

The first variety is the type par excell-

-ence in this area, and is due, as already shewn, to the wholesale inhalation of fine lead dust. I will quote several actual cases coming under my own ob--servation and taken from notes:-

1. Robert S. Appearance:- Very marked asthenia with myotatic irritability of the pectoral muscles; very sallow almost cachectic; features are pinched; lower part of face, especially lower eyelids are puffy. Skin has slight icteric tint. He has no desire for food, and has marked feeling of "biliousness" when presented with food. He has had copious vomiting during the last few days, especially when exposed to the fumes from galvanised metal. There is marked fibrillary tremor of the fingers; Knee jerks are markedly exaggerated; Marked dizziness. He is es--pecially dizzy in the morning when the vomiting takes place; able to take food later in the day; Has all the cardinal symptoms of anaemia. He complains of a considerable degree of cramp in the leg muscles; Has spurious clonus of the ankle joints when stand--ing on the toes; definite intention tremor although finger-nose localisation is efficiently performed. The blue or Burtonian line is well marked at gum edge on lower jaw. Has violent colic every day situated just below umbilicus. Colic has lasted at intervals for three and a half months.

Again Wm. T.

Sudden onset of very severe colic; pain re--ferred to area of large intestine,i.e. the hypo--gastric area; came on in spasms every few minutes during which time patient writhed in agony. During the intervals he complained of a dull constant pain which was permanent in character. There was increas--ed abdominal tenderness on manual pressure or pal--pation; He was given morphine at regular intervals throughout the night; no pyorrhoea alveolaris or gin--givitis, hence no blue line on gums. Had intermitt--ent vomiting of thin, green watery fluid; absolute constipation; Pulse very slow (bradycardia) high ten--sion; during the attacks of colic had very severe headache. Bowels relieved by copious enemata of tur--pentine and olive oil; Colic recurred when action of morphine came to an end. Pain recurred for sev--eral days. His appearance showed very marked anaemia; countenance sallow; features pinched and emaciated; abdomen was retracted; Reflexes normal.

Again. Wm.B.

Had been burning for 9 weeks! Pain across abdomen just above umbiliçus, whence it radiated down into each groin; Had no teeth; gums healthy; No blue line; marked constipation; nausea when presented with food but no vomiting; some degree of anaemia. Nervous

System:- No increased activity of deep reflexes either at knee or elbow joints.

In a study of acute abdominal plumbism it is convenient to describe a prodromal stage wherein is found increasing anaemia, with loss of flesh and recurrent attacks of lead colic, which are character--ised by pain of a gnawing or grinding character sit--uated generally just above and to the left of the umbilicus. Many of my cases, however, have varied somewhat from that rule, the pain being situated across the abdomen just below the umbilicus and corr--esponding largely to the region of the transverse colon. This point is also referred to by Legge & Goadby who state that the area of colicy pain is referable to that of the large intestine.

These cases become cachectic; show a pro--gressive anaemia and exhibit a well marked "pinched" appearance of the features. Dull, "rheumatic" pains are complained of in the muscles, ligaments and joints, the last of these being known as lead arthralgia. The face loses natural expression, be--comes apathetic and somewhat mask-like, and the pulse is small and rapid.

Symptoms such as these constitute a warning to the patient (if he knows sufficient to appreciate their significance) to leave work immediately or

apply for employment elsewhere; but it frequently happens that these symptoms are wanting, there being no obvious sign of an insidious accumulation of lead in the system (except slight pallor, which may be overlooked) until, with spectacular suddenness, a man is seized with violent colic, and is found writhing in agony, vomiting profusely, and possibly also suffer--ing from the acute cerebral symptoms associated with a grave degree of poisoning, and the clinical picture of acute plumbism is established.

Such an acute attack is generally ushered in with a metallic sensation in the mouth; violent headache and excruciating pain in the abdomen of a grinding character coming on every few minutes, and, in addition, a constant, dull, aching pain, which is continuous. The acute paroxysm may be relieved by firm pressure on the abdomen, which latter is generally retracted, or the abdomen may be so tender that palpa--tion increases pain, in which case hot fomentations may give relief.

A noticeable feature of the acute condition is the marked slowing of the pulse which takes place whilst the colic is in progress, the pulse feeling small, hard and tense.

Three conditions,then, coexist during the acute paroxysm, viz:- bradycardia; increased arterial

tension and intestinal colic.

The renal functions are also affected, the urine being diminished in amount, sometimes totally suppressed and sometimes containing albumen,although the last is not a constant feature, but never contain--ing blood.

On physical examination all acute cases exhibit very marked loss of flesh and emaciation which is due to serious interference with the nutritional functions of the body by the lead compounds existing in the circulation during the period of absorption. These cases also shew, as already mentioned, marked pallor of the skin which, in the opinion of Legge & Goadby is more due to vaso-motor disturbance than to secondary anaemia. They have demonstrated 1. That the haemoglobin content of the blood is surprisingly high. 2 That the mucous membranes shew much less pallor than the skin surfaces, and 3 That lead workers can be made to flush when spoken to suddenly, or when excited.

The skin surfaces and sclerotics also shew a more or less marked icteric tint indicative of the blood destruction which is occurring and which may be called by the old name of haematogenous jaundice. These findings are all in accordance with my own ob--servations.

The general appearance of the patient be-

-comes considerably altered, the face becoming quite expressionless and mask-like, somewhat resembling the facies of encephalitis lethargica. These appear--ances constitute saturnine cachexia.

Lead colic is prone to nocturnal exacerba--tions and may be accompanied by diarrhoea; but I have never seen a case which exhibited anything save absolute constipation. This phenomenon has been experimentally tested on animals, notably rodents, which had been fed on lead-contaminated food for some considerable time. On opening the abdomen of a rabbit so poisoned Oliver found that short segments of small intestine were in a state of extreme spas--modic contraction due to contraction of the circular muscular fibres. The lumen of such segments was al--most occluded and the bowel itself almost as hard as whip-cord. Abdominal pain is therefore explicable in three possible ways:- (a) Pressure of the contract--ed muscle fibres on the intestinal nerve plexuses; or (b) Attempts on the part of the non-contracted segments to pass on the bowelcontents; and (c) part--ly also perhaps to vaso-motor spasm of the vessels in the splanchnic area.

From the foregoing it would seem that lead possibly has a selective and irritant action on the splanchnic

nerves, and on the central nervous system, acting on the sympathetic system in much the same way as strychnine, viz:- as a vaso-constrictor, increasing the tension of the peripheral vessels, and producing violently increased peristalsis of the small intestine.

Hence it follows that marked and repeated contraction of the renal arterioles must influence the excretion of urine, must, in time, lead to arterio scherosis and the chronic interstitial nephritis of cases which have been exposed to the baneful effects of lead for some five years or more. (Home Office Memorandum January, 1921.)

BURTONIAN LINE.

The most characteristic feature of lead poisoning is the blue or slate-coloured line occurr--ing on the gums and first described by Tanquerel Des Planches. This sign was also observed by Burton and is known as the Burtonian line. This feature, which is not removable by cleansing, consists of bluish-black particles of lead sulphide deposited in the papillae of the gums and occurs only where teeth are present in conjunction with ulceration or pyorrhoea alveolaris. The formation of lead sulphide is supposedly due to the interaction of the Sulphuretted Hydrogen of the food with lead locally stored in the gum. The Burtonian line is most marked on the lower

jaw at the bases of the canine and outer incisor teeth, but may also be present on the upper jaw, where teeth exist, although not to the same density. A blue line may also be faintly visible on the inner aspect of the gum. The teeth are markedly discol--oured and covered with a brownish pulpy fur whilst the odour of the breath is markedly foetid.

Discoloured patches due to similar cause may also be found on the buccal mucosa situated opposite the canine and outer incisor teeth,varying in size from that of a split pea to that of a shill--ing. Blue patches may also be found post mortem on the intestinal mucosa.

Absence of the Burtonian line does not necessarily mean freedom from lead. Given healthy gums and non-carious teeth there may be no trace of pigmentation in the gum, even though lead may be present in the system to a dangerous degree.

I have recently seen a case of abdominal plumbism (Wm.T.) where the symptoms were specially severe and yet no trace of lead sulphide was discov--erable on either upper or lower jaws. On the other hand, a blue line may persist long after the subject has recovered from symptoms of poisoning, and is apparently of no significance except in so far as it denotes the presence of lead in the system. I have

at present a male patient still exhibiting the Bur--tonian line after four and a half months' freedom from symptoms of poisoning. Nevertheless, the Bur--tonian line is a physical sign of paramount import--ance for diagnostic purposes, the discovery of which in doubtful cases of abdominal colic and emesis,will immediately seal the diagnosis. Where a person is exposed to lead dust, especially the dust of lead white, even for a short time, a pseudo-line may de--velop rapidly due to the deposition of lead sulphide on the surface of the gums. Where suspected this condition can be easily detected by cleansing the gums with water acidulated with dilute sulphuric acid,and it will be found possible to remove the sulphide com--pletely. The Burtonian line is not removable in this manner.

Before leaving the clinical aspects of acute abdominal plumbism, it will be necessary to mention another condition which frequently co-exists with the lead poisoning, viz:- Brass-founders' ague. This term is a misnomer as the condition is due to the inhalation of zinc oxide fumes from galvanised metal when the latter is subjected to the oxy-acety--lene flame. This is a frequent complication of the lead condition and greatly adds to the distress of the worker. The symptoms are languor, chilliness

with chattering of the teeth and shivering. There is marked headache, nausea and vomiting. These last symptoms are, in my experience, much the most common, the cutting of galvanised metal being mentioned by the workers as causative of severe dizziness and vom--iting after which they obtain relief. This condi--tion is a temporary one and ceases when the source of irritation is removed, and is only of importance as a complication of lead poisoning aggravating the symptoms thereof.

LEAD ENCEPHALOPATHY OR ECLAMPSIA.

In his monograph on lead, Oliver finds that females are more susceptible to severe lead poison--ing than males, and that they become susceptible at an earlier age period (18-23 years); whilst in males he considers the period 41-48 as being the most sus-ceptible. In this area no females are employed amongst lead, and in my experience lead poisoning in men cannot be restricted to any given age, as many, or more, cases occurring in the young as in the middle aged. There seems, however, to be a definite sus--ceptibility of females to the cerebral complications of lead poisoning which are manifested in "toxic" hysteria, epilepsy and eclampsia. Young women also recover quickly from colic, but are more readily and severely affected on again exposing themselves.

Oliver describes eclampsia as occurring

generally in young girls of 18-20 years, working in the lead stoves of Newcastle where lead carbonate is manufactured. The subject becomes anaemic and grad--ually thinner; there may be a faint blue line on the gums. Later on she develops sickness, but gen--erally no constipation or abdominal pain, and the menses become irregular. Headaches now develop and increase in intensity and she may have a temporary blindness due to the onset of acute neuro-retinitis. The condition may appear just like an ordinary attack of Grand Mal, not generally preceded by an aura. Whilst at work she is generally seized with convul--sions, epilepti-form in nature and beginning on one half of the face, and spreading to the arm and leg on the same side. Ultimately the convulsions involve the whole body, the pulse being slow and hard as we saw in acute abdominal poisoning, and the patient may die in coma. Where the patient survives, the com--vulsions may recur at intervals between which severe headache is complained of, and she may become either maniacal or melancholic. The urinary excretion is much diminished and albumen is frequently present in amount, although sometimes absent.

In the opinion of Oliver the cerebral symptoms of lead eclampsia are in no way due to the renal condition, i.e. they are not due to uraemia but

to the direct irritant action of the lead itself on the cerebrum. Gradual recovery may take place from the convulsions, but the patient may be left with total blindness which may gradually clear up after three or four months, but which may become permanent.

Apart from eclampsia, cases are on record where other mental phenomena may be observed in per--sons whose tissues are impregnated with lead. In one such instance persistent delusional insanity was traced to plumbism, and, on eliminating the lead from the patient's system, the delusions gradually dis--appeared.

ACUTE NEURO-RETINITIS.

This question has been fully discussed by Oliver especially in connection with his cases of encephalopathy. He describes a marked swelling and cloudiness of the retina with blurring of the margins of the optic disc. The blood vessels exhibit marked narrowing of their lumen. His opinion is emphati--cally opposed to any renal origin of the ocular phenomena and he quotes cases proving the absence of albumen. In this connection Byrom Bramwell throws light upon the subject, stating that an acute retini--tis such as this can be produced by high intra-cran--ial pressure alone; and in his opinion a diagnosis

of cerebral tumour should never be made without first excluding lead poisoning.

Speculation as to the aetiology of optic neuritis in this condition is thus rendered easier when reference is made to the pathological conditions found post-mortem in the central nervous system. All writers are agreed that, where cerebral symptoms exist there is marked oedema of the pia arachnoid and pallor of the brain; lymphocytosis of the cerebro-spinal fluid and microscopic perivascular haemorrhages both old and recent.

Amaurosis rapidly follows after the onset of acute retinitis, and may be permanent, although recovery of sight may occur gradually during several months of convalescence.

THE PATHOLOGY AND NEUROLOGICAL FEATURES OF PLUMBISM.

The classical nervous lesion in plumbism is wrist drop, unilateral or bilateral or, more properly, paresis of the extensor muscles of the fingers pro--ducing flexion of the hand at the metacarpo-phalan--geal joints. This condition is brought about, as all writers are agreed, by a paresis of the extensor digitorum communis but, owing to their special exten--sors, the index and small fingers escape for a time, the paralysis being therefore most marked in the first instance in the middle and ring fingers.

Later, however, the paralytic process extends to other muscles involving the extensor indicis pro--prius and extenso digiti quinti proprius and ultimate--ly possibly also the extensors of the wrist joint itself, viz. extensor carpi radialis and ulnaris - all of which muscles are supplied by the dorsal in--terosseous branch of the radial or musculo-spiral nerve.

At this stage it will be appropriate to say something regarding the aetiology of lead neuritis - concerning which three separate theories are sponsored by different writers.

One school, including Oliver, Erb, and others maintain the central origin of neuritis and hold that the primary lesions are situated in the cells of the Anterior Cornua of the Cervical enlarge-

ment, where the paralysis is Anti-brachial in type and that the resulting lesion is merely a descending degeneration of the lower motor neurone. This theory receives some support from the post-mortem findings of a fatal case of saturnism quoted by Sir Thomas Oliver in which small recent punctuate haemorrhages were found in the cervical enlargement and also evidence of previous haemorrhage in the form of small areas of liquefactive necrosis in the same region. The motor cells in the affected area exhibited granular degeneration and atrophy, and this theory would therefore seem to indicate that lead neuritis is merely a subacute anterior poliomy--elitis - which view is apparently held by Oliver in his monograph of 1891.

Recent writers, however, have shewn histol--ogically that lead neuritis is identically similar in nature to the neuritis produced by any other toxic agent whether alcohol, arsenic or the toxins derived from any infective morbid process.

It has been shewn that the affected nerves, generally the dorsal interosseous of the forearm undergo fragmentation of their myelin sheaths - globules of lipoid material appearing in clusters, and also proliferation of the neurilemma takes place with multiplication of the nuclei in relation there--to. The axis cylinders finally disappear, and it

is claimed that the resultant condition represents true wallerian degeneration extending even to the terminal nerve filaments situated in the substance of the voluntary muscles.

Some degree of doubt has been cast on this hypothesis by Gombault from experiments which he made with guinea pigs chronically poisoned with lead. He found that the peripheral nerves exhibited merely areas of degeneration, the intervening portions being comparatively normal or, in other words, the degeneration affected segments which were not con--tinuous.

It was also shewn by Gombault that the degeneration affected merely the myelin sheath, the axis cylinders remaining normal and to this form of neuritis was given the name névrite segmentaire pér--iaxile. It is quite possible that these findings represent merely an early stage in the development of true wallerian degeneration.

Yet another hypothesis has been advanced by Legge and Goadby who allege that the fundamental lesion in chronic lead poisoning consists in the multiple, punctuate, perivascular haemorrhages al--ready noted in connection with the spinal cord and which are also scattered throughout the body includ--ing the peripheral nerves. Subendoneurial haem-

-errhages produce in their view, a pressure neuritis.

It is now apparently generally accepted that the nerve lesion produced by lead is peripheral especially in view of the fact that recovery from even severe paralysis is not merely possible but the rule either in whole or in part. On microscopic examination of the spinal cord it is found that the anterior horn cells at the level of the sixth and seventh segments (Laslett and Warrington) show marked eccentricity of their nuclei; that the nissl bodies of the cell protoplasm are dispersed over the body of the cell in the form of fine powder; and that frequent--ly in the centre of a cell there is found an actual disappearance of the blue colouring matter or chrom--atolysis.

These changes are regarded as secondary to the degeneration found in the Anterior Nerve roots of the sixth and seventh cervical segments and indicate an altered state of functional activity.

As already mentioned, the cardinal lesion involves the digital extensors leading ultimately to a condition of drop wrist where it is impossible to extend the fingers or dorsiflex the hand. The grasp is also noticeably weakened not through paresis of the flexor group of muscles but through inability of these muscles to function properly from lack of purchase.

On examination of such a case there is found marked swelling of the dorsum of the wrist which may be due to:- A. Thickening of the extensor tendons or B. Undue prominence of the carpus, and is referred to as Gubler's tumour.

The onset of neuritis is followed, like any other motor neuritis, by marked atrophy in the affect--ed muscles and with the following histological appearances:-

1. The transverse striation may be present but is often lost.
2. The muscle nuclei are proliferated.
3. In advanced cases the sarcolemma may contain gran--ules only.
4. The connective and adipose tissues between the muscle fibres are increased in amount.

All the muscles involved in the nerve lesion exhibit the reaction of degeneration and in addition to those muscles above enumerated one must add the two exten--sors of the thumb which may become involved at a later stage.

It is important to note that the Brachio-Radialis (supinator longus) is exempt in this type of paralysis, and, as will be shewn later, is homologous with the Tibialis anterior. Similarly to arsenical poisoning, lead may show a selective affinity for the

peroneal nerve and produce a condition of drop foot involving the peroneus longus, Brevis and Tertius muscles,together with the extensor digitum longus. In this form of paralysis there is much difficulty in locomotion especially in climbing or descending stairs- contraction of the Tibialis Anterior producing an inversion of the foot thereby compelling the patient to walk on the outer border.
Weakness is felt in the limbs, the electrical re--actions are altered as before, but atrophy is not a very conspicuous feature.

Two other well recognised forms of palsy are recorded in the literature and they are:-
1. Erb-Duchenne Paralysis, and
2. Aran-Duchenne Paralysis.
In the former the muscles of the upper arm are invol--ved especially the deltoid which may be involved alone, in which case the patient finds himself unable to raise the arm above the shoulder.
The muscles generally affected in this lesion are 1. Deltoid. 2. Biceps Brachii.3. Brachialis Brachii. 4. Supinator Longus; 5. Supra-Spinatus. 6. Infra-Spinatus.

When the palsy is fully developed the arm will be seen to hang limply by the patient's side slightly adducted and rotated inwards by the action

of the pectoral muscles, whilst the forearm is partly pronated from failure of the powerful supinator action of the biceps.

ARAN-DUCHENNE PARALYSIS.

In this form of palsy the muscles involved are the Interossei and the lumbricals producing an appearance similar to that in progressive muscular atrophy.

In addition to the foregoing there are many cases on record of atypical paralysis involving either single muscles or groups of muscles including those of the eyeball and occurring apparently at random. There is also a form of sudden general muscular involvement which has been described by several writers as resem--bling Landry's acute ascending paralysis.

This condition may develop independently or may sup--ervene within a few hours or days upon an already established classical lesion. The muscles of the body are paralysed en bloc, and throughout their entire length, generally commencing in the legs and advanc--ing upwards, save to those of the head and neck which fortunately escape. The respiration can thus be maintained until the condition clears up, which it always does within a very few days.

I have seen no cases of neuritis in this area, which fact may be explained by the observation that air-borne lead poisoning is a very acute condi-

-tion and is due to poisoning with the soluble salts of lead whereas it has been shewn that lead neuritis is best fostered by metallic lead in any form adminis--tered over a considerable period of time.

COMMENTARY ON PATHOLOGICAL PROCESSES.

The fundamental lesion in lead poisoning, according to the findings of Legge and Goadby, i.e. the lesion to which practically all the morbid changes can be primarily attributed is vascular in nature.

Damage to the endothelial lining of the capillaries and the venules from the irritant action of lead in the circulation - with later on a hyaline degeneration of the muscular coats of the arterioles, leads to yielding of the vessel walls and the pro--duction of multiple punctuate haemorrhages through--out the tissues of the body.

To these haemorrhages some of which are microscopic in dimensions Legge and Goadby attribute all the pathological end-results of lead poisoning including the production of peripheral neuritis, and they have shewn histologically that haemorrhages can be demonstrated within the fibrous nerve sheaths exert--ing pressure on the axis cylinders with presumably destructive effect.

The vague "rheumatic" pains which I have frequently noticed in my own patients are attributable,

perhaps rightly, to multiple haemorrhages in the periarticular fibrous tissues and constitute what is known as lead arthralgia.

With regard to the thoracic and abdominal viscera the same authors seek to correlate the lesions found there with the same primary cause; they have described marked congestion of the splanchnic vessels, congestion of the Hepatic, splenic and pulmonary capillaries and congestion of the renal arterioles. In all cases interstitial haemorrhages are described especially in relation to the venules which, when organised and reduced to fibrous tissue, produce pressure atrophy of the parenchyma. The same process is seen through--out the central nervous system especially in cases of fatal encephalopathy either in man or in animals experimentally killed - haemorrhages new and old in all situations together with marked firmness and pallor of the brain there being also an increase of the cerebro-spinal fluid at the base of the brain and in the lateral ventricles.

It is interesting to note that in many fatal cases where quantitative estimation has been carried out, practically no lead has been demonstrated in the brain tissues, and that therefore convulsions and coma are not attributable to the presence of lead <u>per se</u> but to the effects of lead upon the circulation

and upon the highly differentiated tissues of the part.

As already remarked in the section on acute optic neuritis there is conclusive evidence of high intra-cranial pressure before and during the onset of encephalopathy with marked flattening of the cerebral convolutions including the Rolandic areas demonstrable post mortem.

It seems probable that the convulsions which generally strongly resemble those of Grand Mal, are due to high intra-cranial pressure, yielding of the vessel walls with multiple perivascular haemorrhages and transudation of serum into the sub-arachnoid space, together producing the gross lesions noted above. In addition to these macroscopic lesions the cortical cells shew the same histological appearances as already noted when dealing with the cells in the anterior cornua of the cervical enlargement.

From the available literature on the subject, it is probable therefore that the vascular lesions alone may account largely for the cerebral symptoms in encephalopathy viz:- "toxic" hysteria, convulsions and coma, but as regards lesions in the abdominal viscera it is hardly reasonable to suppose that haemorrhage alone can constitute the main or only factor. There is strong evidence to show that lead,

in common with many other poisons whether inorganic, organic or bacterial in nature, has a distinctly poisonous effect on parenchymatous tissues generally, the cells of which exhibit atrophy, irregularity, granular and even fatty degeneration long before fibrosis has become marked.

In this connection a case was quoted by Sir Thomas Oliver in which a child, born of parents both of whom were saturated with lead, died some three weeks after birth showing marked marasmus. A post mortem examination demonstrated marked cirrhosis of the liver similar in appearance to that found in congenital syphilis, being intercellular in type and showing small round cell infiltration with atrophy of the hepatic cells and no mention of haemorrhages large or small.

In the kidneys, likewise, marked increase of interstitial tissue was noted with granular degen--eration and atrophy of the cells in the convoluted tubules constituting, in his opinion, a parenchymatous nephritis.

He observed also that where death supervened after a massive dose of lead as in eclampsia the epithelial cells of the convoluted tubules became en--larged exhibiting cloudy swelling and fatty degenera--tion ultimately breaking down and filling the interior

of the tubules with their debris.

Concurrently with these lesions there appeared a thickening of Bowman's capsule due to proliferation of the lining cells, and also an in--crease in the number of cells between the coils of the glomerular tuft. There was also an increase in the cells outside Bowman's capsule, and from this as a focus the small round celled infiltration penetrated between the convoluted tubules causing an increase in the connective tissue framework of the kidney.

These findings are upheld by Prof. W. Blair Bell in his brochure on lead therapy in which he re--gards massive dosage of colloidal lead as productive of a parenchymatous nephritis with the same micros--copic changes as noted above, and in which there may be partial suppression of urine, which casts and albuminuria.

It may therefore be assumed that where a person has received one or more massive does of lead either in a colloidal or soluble form the resultant renal lesion is principally parenchymatous in nature, whereas the perivascular small-celled infiltration (probably consisting of connective tissue corpuscles) is merely a response to the irritant action of lead present in the circulation.

It therefore follows that an individual who has in--gested lead, particularly metallic lead, over a long

period and in small quantities will exhibit a chronic interstitial or ischaemic nephritis which cannot be distinguished microscopically from that produced by alcohol.

Before leaving the question of pathology, mention might be made of the two chronic forms of lead poisoning which are generally concomitant, and which are a fruitful cause of death in persons who have absorbed lead over a long period generally in the course of their employment, viz:-

1. Chronic interstitial, granular, or small red kidney, and
2. Arteriosclerosis, including obliterative endarteritis. With regard to the latter, obliterative endarteritis is produced by the irritant action of the lead present in the circulation upon the tunica intima of the arterioles as shown above. These chronic cases present the same clinical appearances as do cases of hyperpiesia and vascular degeneration from any other cause, and it must be emphasised that they may develop convulsions and coma due entirely to uraemia and not to the circumstances found in acute encephalopathy.

In this connection also a retinitis may be developed which is purely albuminuric in origin and appearance, showing marked swelling of the disc, and

extensive patches of exudation around the vessels. Transient loss of sight may be complained of, from which total recovery may take place within a few days: but it may also be presumed that in such cases the action of lead may be upon the visual centre and not upon the peripheral organ especially as no deleterious changes may be seen by the ophthalmoscope.

It now only remains to be said that lead is excreted by both the kidneys and the large intestine. In the former case, lead can be recovered from the urine only during and shortly after an acute attack of poisoning and is apparently only excreted via the kidney when present in the body in large and toxic amount and is also accompanied by a variable degree of albuminuria.

The normal mode of excretion appears to be the mucosa of the large bowel which is seen on post-mortem examination to be stained black from the production of lead sulphide from the ileo-caecal sphyncter downwards.

CHANGES IN THE BLOOD.

The changes found in the peripheral blood which are characteristic of industrial lead poisoning are also markedly seen when lead is administered therapeutically in the collidal form in the treatment of malignant neoplasms.

These changes affect principally the red cells which show a marked and progressive secondary anaemia with considerable reduction in the amount of haemoglobin per cell. There is a curious distribution of the pigment which assumes the appearance of a life-belt being arranged round the periphery of the cell, leaving a clear central area. This phenomenon was well seen in the films taken from my own patients.

The most important change, however, is the occurrence of "stippling" in the red cells, or punct--uate basophilia, and consists in the presence of basophile staining granules of varying size either disposed round the periphery of the cell or scattered throughout the pigment and which are well seen when the film is stained by Leishman's method.

These stipples appear early in the peripheral blood and are regarded as a very strong diagnostic point in favour of lead poisoning where a case is otherwise under suspicion.

The granules appear as bright blue points ten to twenty or more in number and, as already noted, vary greatly in size. Where large, the condition is known as "coarse basophilia", and the granules are arranged round the periphery; otherwise they resemble very fine dots, and are scattered uniformly through--out the cell.

Polychromasia is also a very common phen-

-omenon in lead poisoning in which there is a diffuse greyish-blue coloration of certain of the red cells when stained by Leishman's method. This may be due to changes in the constitution of the haemoglobin, but may also be due, as suggested by Blair Bell, to a further fine division of the granules with diffusion of their substance throughout the cell.

Stippling may also be observed in nucleated red cells if and when they appear in the peripheral blood, and from this it is obvious that degenerative changes associated with the formation of stipples can occur at a very early stage in the life of a red cell.

As in all other grave forms of anaemia, abnormally formed types of erythrocytes may appear in the circulation, poikylocytosis and anisocytosis having been noted.

WHITE CELLS.

The changes seen in the white cells are of less importance, there being occasionally a relative increase in the coarsely granular oxyphils. At other times a number of curiously streaked forms of white cell may be found as large as polymorphs and showing a streaky cytoplasm resembling large hyaline cells in size and shape. Occasionally cells resembling polymorphs may be found whose granules instead of staining pink assume a purple tinge.

Lastly it may be remarked that the icteric tint observed in the skin and sclerotics of advanced cases of lead poisoning is due largely to destruction of red blood corpuscles and is therefore haematogenous in nature.

Where the dose of lead is massive, a large amount of bile may be found in the urine, but like--wise there may only be an excess of urobilin and the Van Der Bergh reaction of the blood serum is indirect--ly positive.

DIAGNOSIS AND TREATMENT.

Where prevalent in a given area, lead poison--ing in its acuter form should presemt no difficulty in recognition especially where marked cachexia co--exists with the Burtonian line.

Where, however, a patient presents himself during the stage of absorption much more difficulty is experienced in arriving at a diagnosis unless a care--ful enquiry is made into the history and clinical features of the case. It is in such cases where a blood film exhibiting punctate basophilia is of prime importance in clinching the diagnosis.

The ideal method of treating all conditions due to lead is undoubtedly by preventative means. Regular and systematic examination of all operatives employed in lead works in order to exclude all those

exhibiting any of the prodromal signs of poisoning, and also those, who, having had repeated attacks of plumbism have shewn themselves intolerant of the poison and constitutionally unfitted for work in lead processes.

It is suggested by Legge and Goadby that a blood film be taken in all suspicious cases with a view to establishing the presence or absence of stipp--ling; Not less than 100 separate microscopic fields must be examined before a blood film can be pronounc--ed free from punctate basophilia.

Any such cases of incipient plumbism should be segregated in another part of the works where al--ternative employment should be available far removed from lead dust or fume in any form until such time as their tissues appear to be free from the metal. Recovery may be gauged clinically by a return of healthy colour to the face, increase in weight, com--plete cessation of abdominal pains (which may recur intermittently for many weeks, and seem to be associated with the excretion of lead via the large bowel) and improvement in the blood picture.

Other points in prophylaxis are, as already mentioned in the beginning, avoidance of working on an empty stomach, and scrupulous care in the disposal of the lead fume, which should be removed from the

zone of operations by some species of exhaust draught apparatus of which many are in use.
To this end respirators have also been recommended but are not always convenient for wearing, in which case the workman should avoid the fume by standing on the windward side whilst using the oxy-acetylene flame.

Poisoning from metallic lead adhering in small particles to the hands as in the case of plumbers and file-makers requires merely care in personal hygiene before partaking of food.

When called in to attend a case of acute abdominal plumbism, one must bear in mind the cardin--al features of the underlying syndrome and must treat accordingly. It is of prime importance to reduce the blood pressure and to relieve the violent grind--ing abdominal pain, and also to avoid cerebral com--plications, such as convulsions and coma. To this end one might give a hypodermic injection of veratrone (the active principle of veratrum viride) in doses of ½ - 1 cc. or any one of the nitrite vasodilators.

Amyl Nitrite capsules MV are recommended by most writers, and should be accompanied by an analgesic such as one of the drugs of the morphine series.
It is noteworthy that repeated administrations of the analgesic, preferably accompanied by atropine require to be given in most severe cases extending

sometimes over several days as there is a great tend-
-ing for the pain to recur when the effects of the drug begin to wear off.

In addition to the foregoing the primae viae must be evacuated by copious enemata containing turpentine and olive oil, whilst temporary relief from pain may be obtained by the application of firm pressure to the abdomen and hot fomentations. The patient indeed may be found on the first visit with his fists clenched and firmly pressed into the abdomen or bent over the back of a chair in vain endeavour to obtain relief from his agony.

Lead sickness is a very distressing feature which may last several days during which time the patient can take no food and many even reject water. In such cases a starvation acidosis supervenes, which must be combated by saline and glucose enemata, whilst nutrient enemata should also be given to keep up the patient's strength.

The urgent symptoms having been allayed, one must now attempt to eliminate the lead from the body tissues, which is naturally a very tedious and pro-
-tracted process. In addition, relapses of pain may recur at any time during convalescence, being precipi-
-tated by indiscretions of diet particularly in regard to alcohol.

As excretion is effected almost entirely via

the large bowel and only very slightly in the urine after the acute stage has passed, purgatives must be exhibited to keep the primae viae regularly open; and in addition dilute acidulated drinks are given in the hope of producing an innocuous and insoluble compound (lead sulphate), the prescription containing dilute sulphuric acid and a saline cathartic.

Potassium iodide is the drug widely recommended for the purpose of eliminating lead from the tissues - a soluble iodide of lead being produced by the exhibition of this drug. Considerable care must, however, be exercised in regard to dosage inasmuch as a large dose of iodide may liberate a lethal quantity of lead from the patient's own tissues and a fatal issue result.

A case in point is cited by Oliver where a dose of 7 grains of K.I. precipitated death in an old woman who was the subject of chronic poisoning. The dose generally recommended is about 3 grains given with saline cathartics thrice daily.

A nourishing diet must also be provided so soon as the patient is in a condition to retain food in the stomach particularly a diet rich in fats. The blood must also receive attention, iron and arsenic being given to combat the anaemia, and stimulate the bone marrow to further efforts.

The other form of acute industrial poisoning namely

encephalopathy must be treated in the same way as above, by reduction of the blood pressure and elimina--tion of the poison, and, if occurring in a female, total prohibition from returning to lead processes of any kind.

Where peripheral neuritis has supervened the first objective in treatment is attained by the applica--tion of light and comfortable splints, which are worn night and day and only discarded after the re--turn of adequate voluntary power. From the beginning, massage and galvanic electricity must be employed to prevent degeneration of the affected muscles by pro--liferation of fibrous and fatty tissues.

When nerve regeneration begins to be mani--fest faradic, stimulation can be employed together with exercises, and curative occupations. The most valuable drug to exhibit during the stage of nerve regeneration in peripheral neuritis is strychnine, which may also be used for any temporary blindness occurring during the course of lead poisoning. Chronic granular kidney occurring as an end result of very protracted cases of lead absorption must be treated on general lines for the prevention of uraemia so also arterio-sclerosis with the usual accompaniments of hyperpiesia and tendency to cerebral apoplexy.

Lastly, it is the duty of all medical

Practitioners to notify all cases of suspected poison-
-ing contracted industrially to H.M.Chief Inspector
of Factories, Home Office, London, who, in turn,
notifies the local Medical Officer to make an examina-
-tion of the case, and to grant a certificate if the
diagnosis be upheld.

The individual is then entitled to receive
Compensation under the Workmen's Compensation Acts
during the period of his disability, and until he is
physically able to undertake alternative employment.

S U M M A R Y.

1. Industrial poisoning can be produced with great rapidity from inhalation of fumes of the soluble salts of lead.
2. Where fumes are present in sufficient density four or five weeks are sufficient to produce profound cachexia, wasting, and anaemia.
3. The individual is now liable to violent attacks of abdominal pain accompanied by high arterial tension and slowing of the cardiac rhythm.
4. If renal complications occur they are parenchy-
-matous in nature, and albumen may be found in the urine.
5. Alternatively, cerebral complications may super-
-vene especially in females with "toxic" hysteria, convulsions, and coma, generally followed by

death.

6. Where blindness ensues in last case, it is due to high intra-cranial pressure producing an acute optic neuritis.

7. Pigmentation may be found in the gums and cheeks and post-mortem in the intestine.
In the first case, the pigmentation or blue line is of great diagnostic importance but not necess--arily an indication of poisoning, merely indic--ating presence of lead in tissues.

8. Lead salts have a destructive action in highly specialised tissue, notably the blood and renal cells on which the chief stress apparently falls.

9. Blood changes include profound secondary anaemia with or without normoblasts and stippling of the red cells.

10. In more chronic poisoning neuritis may occur generally affecting the dorsal interosseous nerve of the forearm and is a peripheral lesion.

11. Long-continued irritation of renal capillaries produces a chronic interstitial nephritis or small red kidney.

12. Chronic poisoning fosters arterio-sclerosis and obliterative endarteritis.

13. A frequent cause of death in chronic cases is uraemia or cerebral haemorrhage.

14. Prevention is better than cure; only persons having a high tolerance to lead, or where ex--cretion can keep pace with absorption should be employed in lead.processes.

15. Where poisoning is contracted treatment must aim first at giving relief and later at elimination.

16. The classical drug to be exhibited is potassium iodide in small doses, accompanied by acidulated drinks and saline purgatives.

17. Cases of peripheral neuritis should receive treatment for paralysed muscle groups and strychnine therapy when nerve regeneration is becoming established.

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